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Polychlorinated Biphenyls and Organochlorine Pesticide Residues in Nile Perch (*Lates nilotica*) from Lake Victoria, Uganda

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Abstract: Concentrations of polychlorinated biphenyls and organochlorine pesticides were determined in muscle and liver samples of Nile Perch (*Lates nilotica*) caught from the Ugandan part of Lake Victoria. Our overall objective was to assess human exposure risk to these chemicals through consumption of fish. Six organochlorine pesticide residues and 3 polychorinated biphenyl congeners were found in fillet samples in the following proportions: Hexachlorobenzene (6.7%), dieldrin (3.3%), p,p'-DDE (83.3%), o,p'-DDD (6.7%), p,p'-DDD (3.3%), p,p'-DDT (20%), PCB-153 (13.3%), PCB-138 (13.3%) and PCB-180 (16.7%). The concentrations of these contaminants in muscle were generally low. The mean concentration of total DDT in muscle was 0.001 mg kg^{-1} fresh weight and the highest recorded level was 0.003 mg kg^{-1} fresh weight. DDE constituted on average 94% of total DDT in fillet. In liver samples, 9 organochlorine pesticide residues and 4 PCB congeners were found in the following proportions: Hexachlorobenzene (20%), α-HCH (13.3%), β-HCH (6.7%), lindane (10%), dieldrin (36.7%), p,p'-DDE (83.3%), o,p'-DDD (3.3%), p,p'-DDD (33.3%), p,p'-DDT (13.3%), PCB-52 (3.3%), PCB-101 (16.7%), PCB-153 (16.7%) and PCB-138 (13.3%). The mean total DDT was 0.003 mg kg^{-1} fresh weight, with the highest concentration of 0.01 mg kg^{-1} fresh weight. The mean residue levels of total DDT and dieldrin were 0.12 and 0.3% of the respective German maximum residue limits. The estimated average adult daily intakes of the total DDT residues through fillet consumption was only 0.0005% of FAO/WHO maximum acceptable daily intake.

Key words: DDT, DDE, dieldrin, endocrine disruption, fish

INTRODUCTION

Polychlorinated Biphenyls (PCBs) and organochlorine pesticides like DDT are among the anthropogenic chemicals that are now known to disrupt the endocrine system in humans and wildlife. The potential effect of these chemicals on human and ecosystem health is a major concern among the scientific community, especially the ecotoxicologists. In humans, in utero exposure to PCBs is associated with neurobehavioral deficits (Rogan *et al*., 1987) and there is increasing support for an association between breast cancer risk and exposure to DDE (Wolf *et al*., 1993).

In wildlife species, evidence of the effects of endocrine disrupting chemical is overwhelming. Reproductive abnormalities have been observed in several wildlife populations living in polluted areas (Guillette *et al*., 1996). Laboratory studies have confirmed the effects of these chemicals on the development and expression of sexual characteristics in fish (Toft *et al*., 2003) amphibians (Hoyes *et al*., 2002) reptiles (Willingham *et al*., 2002) and birds (Feyk and Giesy, 1998). So far, this evidence has been gathered in industrialised countries especially in western Europe and North America.

We earlier reported occurrence of organochlorine pesticides in breast milk of mothers residing in Kampala city and in rural areas of Iganga district in Uganda (Ejobi *et al*., 1996). Fish consumption is one of the major routes of human exposure to PCBs and organochlorine pesticides. In this study, we provide evidence of the occurrence and levels of PCBs and organochlorine pesticides in Nile Perch caught from the Ugandan part of Lake Victoria. Our objectives were to assess human exposure risk to these chemicals through consumption of fishand to examine the environment load of these pollutants in the Lake Victoria ecosystem using fish tissues as the environmental specimen.

MATERIALS AND METHODS

Sample collection: A total of 60 samples (30 muscle tissue and 30 liver) of Nile perch (*Lates nilotica*) were collected at Ggaba fish landing site in Lake Victoria. All the samples

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were collected between 6.00 and 9.00 a.m East African Time. The Codex Alimentarius Committee sampling guidelines were followed (CAC, 1993). About 100 g of the tissues were collected and were wrapped in aluminium foils and transported in a cool box with ice parks to the Faculty Veterinary Medicine at Makerere University. The samples were then reduced to about 20 g and were immediately frozen. The samples were later transported frozen to the University of Saarland, Germany where the chemical analysis was carried out.

Chemical analysis of samples: Extraction and clean-up was performed according to the US-EPA Method 608 (1980) with slight modifications to account for differences in fat contents. Briefly, the method was as follows: Ten to fifteen g of muscle and 1 to 3 g of liver samples were used for extraction. The samples were ground in a porcelain mortar containing anhydrous sodium sulfate to yield a dry free-flowing powder. Sea sand was added to the mortar during grinding. Each sample was spiked with 20 μL of a surrogate during the extraction process as a quality assurance measure of the analytical method.

The dry free-flowing powder was transferred into a glass extraction column of length 30 cm and an internal diameter of 2 cm. The dry column was then eluted with 80 mL of dichloromethane with the first 40 mL allowed to stay in contact with the powder for 20 to 30 min. The eluate was collected in a pre-weighed round bottom flask.

Dichloromethane in the eluate was removed using a rotary evaporator at about 35°C and under reduced pressure of 0.5 bar. The flask was weighed until a constant weight was obtained and the amount of extractable fat determined. The glass column was filled with about 10 cm of distilled petroleum ether. Florisil® (3% water) was then added to the column depending on the amount of fat. Uniform packing of Florisil® was ensured by gently tapping the column.

The fat extract was re-dissolved in 2-5 mL of petroleum ether and pipetted on to the top of the column. The flask was rinsed twice with about 2 mL of eluting mixture. This was followed by elution of the column using a mixture of petroleum ether/dichloromethane at the ratio of 4:1. The flow rate of the elution mixture was controlled so as not to exceed 5 mL min^{-1}.

The eluate was concentrated to a small volume (approximately 5 mL) using a rotary evaporator at about 35°C under reduced pressure at -0.6 bar. This was then transferred to a 10 mL flask and evaporated to dryness. One milliliter of internal standard was added to the flask, mixed thoroughly with a whirl mixer and then transferred to autosampler vials ready for gas chromatography.

A gas chromatograph PE Sigma 300 with AS-100 autosampler and Spectacle analysis system was used. Quantification of the residues was carried out using Spectacle® software program (LabControl, 1994). The levels of the pesticide residues in ng μL^{-1} obtained from the Spectacle® report were converted to mg kg^{-1} fat and mg kg^{-1} fresh weight using Quanti 98® software program.

Data analysis: The data were analysed in Excel® programme. Descriptive statistics were computed. Human exposure risk assessment was done by comparing the observed contaminant level with the German maximum residue limits. Adult human daily intake of residues of dieldrin and total DDT through consumption of fillet was calculated taking average fish daily fish consumption of 0.03 kg as reported by MAAIF (1996). Intake of the contaminants by cases of extreme eaters of 1 kg of fish per day as described by Muller (1987) was also computed.

RESULTS AND DISCUSSION

Table 1-3 present the levels in mg kg^{-1} fresh weight of PCBs and organochlorine pesticides detected in the tissues analysed. The levels are presented without correcting for percent recoveries. Six organochlorine pesticide residues and 3 PCB congeners were detected in fillet samples in the following proportions: hexachlorobenzene (6.7%), dieldrin (3.3%), p,p'-DDE (83.3%), o,p'-DDD (6.7%), p,p'-DDD (3.3%), p,p'-DDT (20%), PCB-153 (13.3%), PCB-138 (13.3%) and PCB-180 (16.7%). No residues of endosulfan, α-HCH, β-HCH,

Table 1: Levels (mg kg^{-1} fresh weight) of PCBs in filet and liver samples

	Filet			Liver			
N = 30	PCB-153	PCB-138	PCB-180	PCB-52	PCB-101	PCB-153	PCB-138
Mean	0.0001	0.0001	0.0001	0.0001	0.0002	0.0002	0.0002
S.D	0.0002	0.0004	0.0004	-	0.0004	0.0004	0.0004
Median	n.d	n.d	n.d	n.d	n.d	n.d	n.d
Maximum	0.001	0.0005	0.0005	0.0005	0.002	0.002	0.002
No. positive	4	4	5	1	5	5	4
Positive (%)	13.3	13.3	16.7	3.3	16.7	16.7	13.3

No. positive = Number of samples with detectable levels of PCBs

Table 2: Levels (mg kg^{-1} fresh weight) of organochlorine pesticide residues in fillet samples

N = 30	Fat (%)	HCB	Dieldrin	p,p'-DDE	o,p'-DDD	p,p'-DDD	p,p'-DDT	Total DDT	(%) DDE*
Mean	1.0	0.0001	0.0001	0.0005	0.0001	0.0001	0.0002	0.0006	94
S.D	0.7	0.0001	0.0001	0.0003	0.0001	0.0001	0.0002	0.0005	16
Median	1.0	n.d	n.d	0.0005	n.d	n.d	n.d	0.0005	100
Minimum	0.2	n.d	n.d	n.d	n.d	n.d	n.d	n.d	-
Maximum	3.4	0.0005	0.0005	0.002	0.0005	0.001	0.003	100	
NO. Positive	-	2	1	25	2	1	6	30	-
(%) positive	-	6.7	3.3	83.3	6.7	3.3	20	100	-

No. positive = Number of samples with detectable residue levels; (%) DDE = p,p'-DDE/total DDT; n.d. = not detected

Table 3: Levels (mg kg^{-1} fresh weight) of organochlorine residues in fish liver samples

N = 30	Fat (%)	HCB	α-HCH	β-HCH	Lindane	Dieldrin	p,p'DDE	o,p'-DDD	p,p'-DDD	p,p'-DDT	Total DDT	(%) DDE
Mean	18.1	0.0002	0.0001	0.0002	0.0001	0.0003	0.002	0.0001	0.0007	0.0001	0.0027	95
S.D	12.9	0.0004	0.0003	0.0007	0.0003	0.0004	0.0023	0.0002	0.001	0.0002	0.0029	15
Median	15.2	n.d	n.d	n.d	n.d	n.d	0.001	n.d	n.d	n.d	0.0015	100
Min.	4.7	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	n.d	50
Max.	57.1	0.002	0.001	0.004	0.001	0.001	0.01	0.001	0.003	0.001	0.01	100
No. +ve	-	6	4	2	3	11	25	1	10	4	100	-
(%)+ve	-	20	13.3	6.7	10	36.7	83.3	3.3	33.3	13.3	-	-

No. positive = Number of samples with detectable residue levels; %DDE = p,p'-DDE/total DDT; n.d. = not detected

lindane, o,p'-DDT, PCB-28, PCB-52 and PCB-101 were found in fillet. The mean total DDT in fillet was 0.001 mg kg^{-1} fresh weight and the highest recorded level was 0.003 mg kg^{-1} fresh weight. DDE constituted on average 94% of total DDT in muscle samples.

In liver samples, 9 organochlorine pesticide residues and 4 PCB congeners were detected in the following proportions: hexachlorobenzene (20%), α-HCH (13.3%), β-HCH (6.7%), lindane (10%), dieldrin (36.7%), p,p'-DDE (83.3%), o,p'-DDD (3.3%), p,p'-DDD (33.3%), p,p'-DDT (13.3%), PCB-52 (3.3%), PCB-101 (16.7%), PCB-153 (16.7%) and PCB-138 (13.3%). The mean total DDT was 0.003 mg kg^{-1} fresh weight, with the highest concentration of 0.01 mg kg^{-1} fresh weight. The mean levels of other pesticides were at or near the detection limit. DDE constituted on average 95% of total DDT in liver samples.

All mean residue levels were far below the respective the German maximum residue limits. The mean residue levels of total DDT and dieldrin were 0.12 and 0.3%, respectively of MRL. The highest total DDT level of 0.003 mg kg^{-1} fresh weight was only 0.6% of the MRL. The estimated average adult daily intake of the total DDT residues through fillet consumption was only 0.0005% of FAO/WHO maximum ADI, while that for dieldrin was only 0.01%. For the case of hypothetical extreme fish eater, the estimated daily intake of total DDT was 0.05% of the FAO/WHO maximum ADI, while that for dieldrin was 2%.

The presence of PCBs and organochlorine pesticides in the fish samples analyses was rather expected. These chemicals persist in the environment and they biomagnify along the food chain. PCBs have mainly been reported in the industrialised countries, though concentrations have declined following a ban in their manufacture and use. This study is the first report on the occurrence of PCBs in fish from Uganda. The concentrations of PCBs observed in this study are generally low, probably due to limited use of this chemicals in the industrial processes in Uganda.

Previous published studies of organochlorine residues in fish in Ugandan water bodies are rather limited. A study in the early 1970s reported DDT residues in Nile Tilapia fillet from Lake Kyoga in eastern Uganda (Sserunjoji, 1994). The present mean total DDT level of 0.0006 mg kg^{-1} fresh weight in fish from Lake Victoria is much lower that earlier reported from Lake Kyoga. The relatively higher total DDT levels in that study by Sserunjoji (1974) could be explained by the fact this was the period of peak use of DDT in the country for control of cotton pests, especially in the districts of Kumi, Soroti, Katakwi, Liraand Apac. These districts are located in the watershed areas of Lake Kyoga. It could also be inferred that DDT levels have generally decreased in aquatic environment in the country.

Elsewhere in the East African region, some studies on organochlorine residues have been done in Kenya. Generally, the levels reported in Kenya are higher those observed in this study. Greichus *et al.* (1978) reported levels of dieldrin (0.003 mg kg^{-1} fresh weight) and p,p'-DDE (0.005 mg kg^{-1} fresh weight) in fish caught from Lake Nakuru, a shallow, alkaline, eutrophic lake located entirely within the Nakuru National Park. Mitema and Gitau (1990), found 9 organochlorine residues (α-HCH 40%, β-HCH 40%, lindane 4%, aldrin 9%, dieldrin 1%, p,p'-DDE 73%, p,p'-DDD 9%, o,p'-DDT 1% and p,p'-DDT 11%) in the Nile Perch fillet caught from the Kenyan part of Lake Victoria. All the levels of the residues in that study were below the ERL, except one sample that had total DDT level of 4.51 mg kg^{-1} fat. Calamari *et al.* (1994) in a study of pollution of t he Winam Gulf in the Kenyan part of Lake Victoria, reported in *Lates nilotica*, mean levels of

p,p'-DDT, p,p'- DDE and p, p'-DDD as 0.0030, 0.0044 and 0.0078 mg kg^{-1} fresh weight, respectively. The highest level of total DDT Kanja (1989). could detect in fish from Rusinga Island in Lake Victoria was 0.094 mg kg^{-1} fresh weight, which is higher that of 0.010 mg kg^{-1} fresh weight observed in this study. In developed countries, the levels of organochlorine residues in fish and other foodstuffs have generally decreased following restrictions placed on their use (UNED, 1992).

CONCLUSION

The Nile Perch (*Lates nilotica*) from the Ugandan part of Lake Victoria is contaminated with low levels of PCBs and organochlorine pesticides. However, the effect of low level and long-term exposure to these chemicals to humans as well as ecosystematic effects can not be ascertained.

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